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Ferrous Metals Recovery at Recovery 1 New Orleans: Performance of the Modified System. Test No. 4.05 and Test No. 4.09 Recovery 1, New Orleans

National Center for Resource Recovery, Inc.
Washington, DC

Prepared for

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16. ABSTRACT

This report documents two series of samplings and the monitoring of energy consumption and shredder hammer wear (collectively Test No. 4.05 and Test No. 4.09) of the upgraded ferrous recovery system that produces a light ferrous product from the processing of municipal refuse at the New Orleans resource recovery project. (Recovery 1). A series of system samplings was conducted for each of two refuse processing lines that provide ferrous to the ferrous recovery system: Line #1--primary trommel and shredder; Line #2--shredder only. Beyond the trommel unders and shredded material primary magnets, the upgraded ferrous recovery system includes an air knife to remove loose contamination and separate light and heavy-gauge ferrous, a light ferrous shredder to liberate attached contamination and densify the light ferrous, and a secondary magnet for cleaning of the shredded light ferrous.

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution, and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources; for the preservation and treatment of public drinking water supplies; and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This report documents testing of the upgraded ferrous metals recovery system used to produce a light ferrous product from municipal refuse at the New Orleans Resource Recovery Project (Recovery 1). The upgraded system reduces nonmetallic and heavy ferrous contamination in the light ferrous product, thereby increasing its market value and possibly the range of uses for the product. This report is intended to provide useful information to designers or operators of facilities which recover ferrous metals from municipal refuse.

Francis T. Mayo
Director
Municipal Environmental Research Laboratory

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ABSTRACT

This report documents two series of samplings and the monitoring of energy consumption and shredder hammer wear (collectively Test No. 4.05 and Test No. 4.09) of the upgraded ferrous recovery system that produces a light ferrous product from the processing of municipal refuse at the New Orleans resource recovery project (Recovery 1). A series of system samplings was conducted for each of the two refuse processing lines that provide ferrous to the ferrous recovery system: Line #1--primary trommel and shredder; Line #2--shredder only. Beyond the trommel unders and shredded material primary magnets, the upgraded ferrous recovery system includes an air knife to remove loose contamination and separate light and heavy-gauge ferrous, a light ferrous shredder to liberate attached contamination and densify the light ferrous, and a secondary magnet for cleaning of the shredded light ferrous.

At usual but documented operating conditions, a set of five samples which included the four output streams and the air knife feed stream were collected sequentially for 30 seconds each. Four sets of samples were collected in the Line #2 series and two in the Line #1 series. The product samples were analyzed for bulk density, particle size, composition, balling of cans and ferrous attached contamination. The secondary magnet tailings and air knife flies samples were analyzed for composition and ferrous attached contamination. The air knife heavies samples were analyzed for bulk density, composition, aerodynamically light or heavy, and can and noncan ferrous attached contamination. Finally, the feed samples were analyzed for bulk density, composition, particle size, and can and noncan ferrous attached contamination. From the analyses of these samples, a materials balance for the system was developed and performance characteristics for the three main pieces of equipment were tabulated. The shredder motor power consumption and specific power were determined for each of the corresponding product samplings. Hammer wear was determined after shredding 58 tons. The report details these results and also describes the processing equipment and test and analytical procedures used.

This report was submitted in fulfillment of Contract No. 68-01-4423 by National Center for Resource Recovery, Inc., under the sponsorship of the U. S. Environmental Protection Agency and covers a period from May 8 to June 5, 1980, with analysis and report completed as of July 1980.

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SECTION 1

INTRODUCTION AND SUMMARY OF TEST RESULTS

The original ferrous recovery system at Recovery 1 [1-4] is depicted in Figure 1 for the operation of the primary processing line, Line #1. For the secondary processing line, Line #2, there is no trommel preceding the shredder; therefore, there is only ferrous scalped from shredded refuse by #171 drum magnet. All ferrous recovery system equipment downstream of the primary magnets is in common use and function for Lines #1 and #2 ferrous recovery. This included a ferrous concentrator

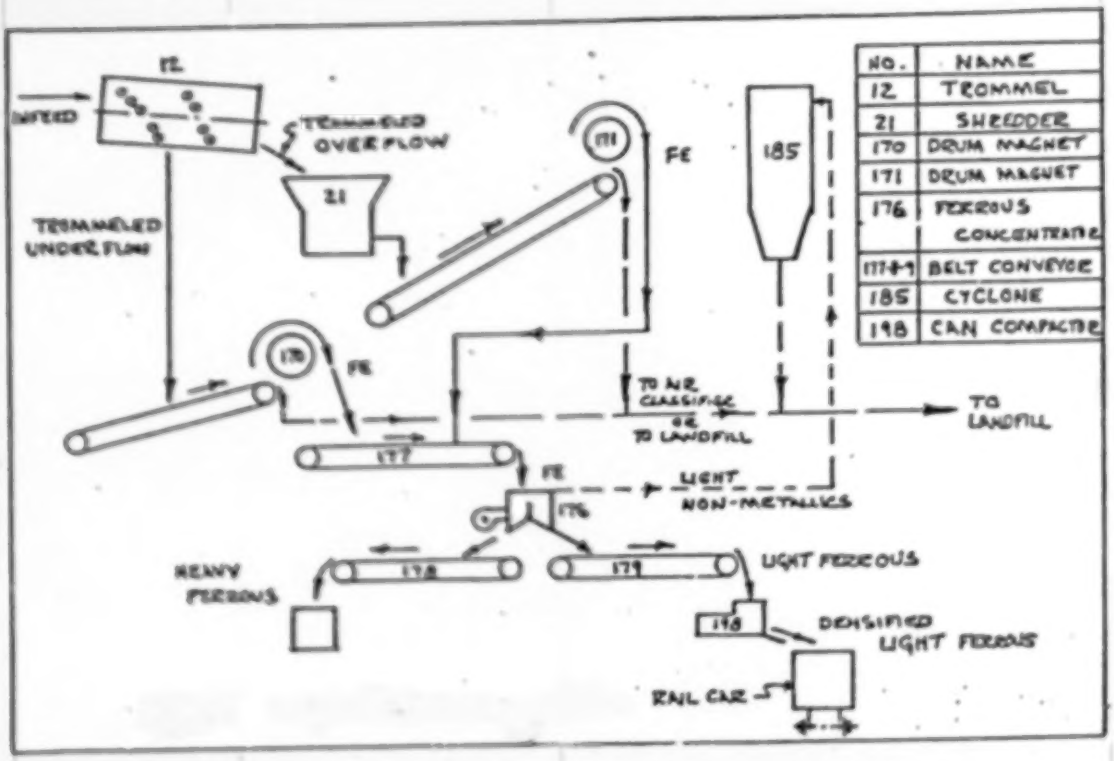

Figure 1. Original ferrous recovery system.

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(#176) that removed light nonmetallics or loose contamination that was carried over with the ferrous by the drum magnet(s) and also separated light from heavy-gauge ferrous. The light ferrous was compacted (#198) to increase the contents in the railcar for shipping to the buyer, a detinner and precipitation-iron dealer.

Operational, product quality, and economic problems were identified for this original ferrous recovery system (FRS), most of which have been reported [5, 6]. To summarize these problems:

(1) there was inefficient primary extraction of ferrous from Line #2 operation because the #171 drum magnet had to be left raised at large air gap to accommodate Line #1 operation, i.e., avoid jams;

(2) the ferrous concentrator (#176) continually had jams at its light ferrous discharge and allowed much large (and small) heavy ferrous into the lights, or product, reducing the system operating time and reducing product quality, respectively;

(3) the product contained 10-16% contamination, only about 10% of which could be removed by air separation, i.e., loose; at this level of contamination, its value and price were low;

(4) the density of the compacted product was significantly less than the 21.5 lb/ft^3 bulk density required for a 2,800 ft^3 railcar to contain 60,000 lb, minimum, thereby incurring shipping penalties;

(5) additional shipping penalties were incurred because of demurrage, or rental of a railcar, while another railcar was being filled as an alternative to no ferrous recovery if an empty railcar could not be delivered promptly when a railcar became full.

The upgraded system designed to alleviate or deal with the aforementioned problems and conditions [5, 6] and meet criteria for the light ferrous product from the upgraded system: maximum contamination, 4%; bulk density, 21.5-26.0 lb/ft^3; and shred size, maximum, 5% less than 1 in., is depicted in Figure 2 and has been in operation since March 1980. It provides ready adjustment of the #171 drum magnet air gap by hydraulic actuators, another ferrous air knife (#207), a light ferrous shredder

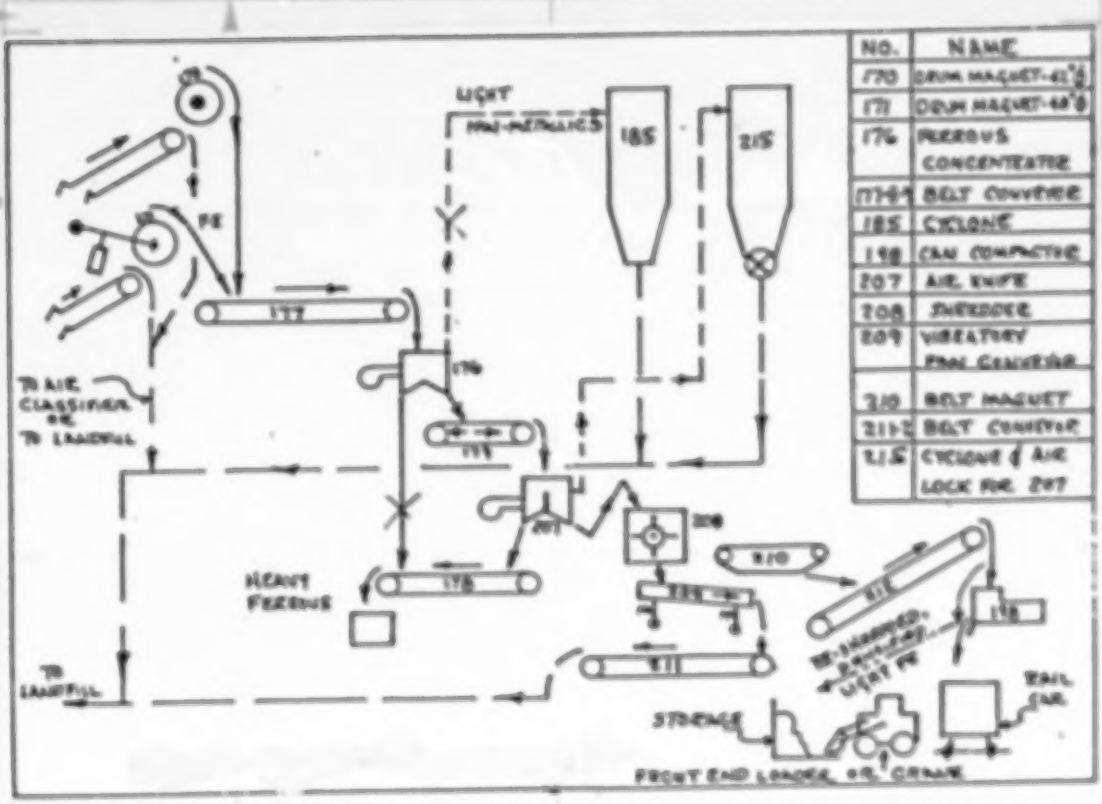

Figure 2. Upgraded ferrous recovery system.

(#208), a secondary magnet (#210), and a storage area. Since operation of the upgraded system commenced, it was determined that the new air knife adequately protected the #208 shredder so the ferrous concentrator (#176) acts now only as a vibrating conveyor and that the product density exceeds the minimum bulk density required so the compactor (#198) has been bypassed.

The current tests included a series of samplings and analyses of the system discharge and feed (to the air knife) streams for usual but documented Line #2 and Line #1 operation as well as monitoring of shredder energy requirements and shredder hammer weight loss or wear. This information enabled compilation of a system materials balance and characterization of performance for each piece of processing equipment: air knife, shredder, and magnet. Section 3 presents these results in detail, whereas they are only summarized here.

The estimated throughput for processing Lines #2 and #1 for the test samplings was 118 and 108 tph, respectively. The

estimated overall recovery (i.e., what percent in the refuse went to the railcar) for the target can ferrous metal was 40% and 37% for Lines #2 and #1, respectively. The estimated efficiency for the adjustable air gap #171 drum magnet was 62% for Line #2 operation.

For Line #2 operation, 64% of the can ferrous metal in the air knife feed was recovered as product; 31% was lost to the air knife "heavies" stream (34% of this was determined to be aerodynamically light and, hence, misreported), 3% to the "flies" stream, and 1% to the secondary magnet tailings. Thirty-six percent of the noncan ferrous metal in the air knife feed reported to the shredder and product. About half of the contamination attached to the can ferrous in the shredder feed was liberated by its processing, reducing the attached contamination from 7.9% to 4.1%. The secondary magnet carried over 9.2% of the loose contamination in its feed. The product rate was 1.63 tph at 26.7 lb/ft^3 bulk density. The product composition was: 0.4% loose contamination; 81.8% can ferrous; and 17.8% noncan ferrous. The total contamination was 4.5%. The ferrous in the product was 10.5%, -1".

For Line #1 operation, 52% of the can ferrous metal in the air knife feed was recovered as product; 40% was lost to the air knife heavies stream (27% of this was determined to be aerodynamically light and, hence, misreported), 7% to the flies stream, and 1% to the secondary magnet tailings. Twenty-seven percent of the noncan ferrous metal in the air knife feed reported to the shredder and product. About half of the contamination attached to the can ferrous in the shredder feed was liberated by its processing, reducing the attached contamination from 7.0% to 3.7%. The secondary magnet carried over 5.4% of the loose contamination in its feed. The product rate was 1.34 tph at 24.5 lb/ft^3 bulk density. The product composition was: 0.3% loose contamination, 84.3% can ferrous, and 15.4% noncan ferrous. The total contamination was 3.5%. The ferrous in the product was 12.7%, -1".

From the monitoring of the power used by the shredder's (#208) 50 hp motor at the time of sampling the product, the power consumption and specific energy were determined. For Line #2, 26 hp were required and the specific energy was 15 hp-hr/ton. For Line #1, 24 hp were required and the specific energy was 17 hp-hr/ton. The shredder's hammers were weighed before and after it processed 58 tons. The wear rate was 0.021 lb hammer weight per ton processed. Without hardfacing, the hammers would be expected to have nearly 1.5 times that wear rate.

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Review of the test results suggests that the air knife blower output should be increased and that adjustment/modification of air knife diverters and baffles should be effected to reduce the loss of can ferrous to the heavies from direct misreporting or from "ricocheting" out of the shredder to the heavies, respectively.

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SECTION 2

EQUIPMENT DESCRIPTION, TEST PROCEDURE, AND SAMPLE ANALYSES

EQUIPMENT DESCRIPTION

The key elements of the modified/upgraded ferrous recovery system have been illustrated previously in Figure 2. The descriptions below specify and illustrate these equipment in more detail. The connected horsepower of the added equipment described below is 124.5 hp. The supplied electric power is 480 V, 3 phase, 60 Hz. One remotely located push button can start the entire system in a time-staggered fashion.

Ferrous Air Knife (#207)

The ferrous air knife was supplied by Mac Equipment Company with a 60 hp electric motor and materials handling fan, plus two adjustable diverter gates. The air knife, as tested, is illustrated to scale in Figure 3 which shows the additional retrofitted baffles (designated by dimensions B, C, D, and 3" x 3" angle iron) to reduce ricochet of ferrous from the shredder into the "heavies" discharge. The air knife chamber is three feet wide. Most of the air from the air knife blower along with the light nonmetallics passes through a duct into a negative-pressure cyclone (#215) capable of handling at least 15,000 ft^3/min of air; the de-entrained light nonmetallics pass through a rotary air lock to conveyor #211 and the solids-free air recirculates to the inlet of the 60 hp air knife blower. Additionally, the blower inlet duct is supplied with an adjustable fresh-air inlet; for all the test samplings this fresh-air inlet was closed. Except for one test sampling (no. 4) during Line #2 operation, in which the lower knife slot had on a 1-1/2" opening, both air knife discharge slots were fully opened.

The principal air knife performance specifications were to process 5 tph of 10 to 15 lb/ft^3 bulk density magnetic product while accommodating peak loads of 6 tph; the composition of the feed was to be 5% (wt.) light nonmetallics, 82% light ferrous, and 13% heavy ferrous. Separation of the feed into the three output streams would be as follows:

(1) light nonmetallics stream--shall contain 75% of the loose nonmetallics in the feed, while

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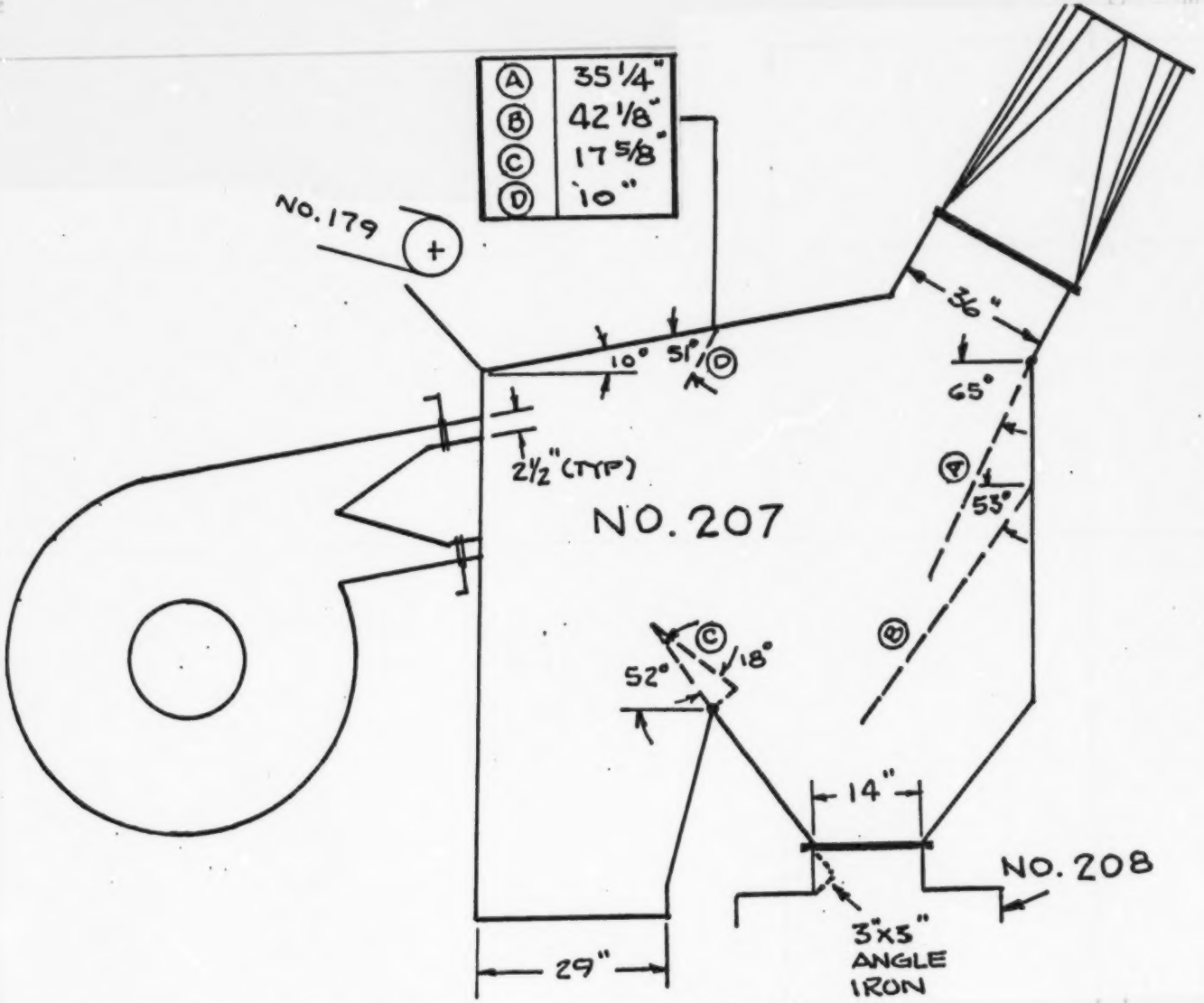

Figure 3. Ferrous air knife showing internal baffles.

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containing no more than 2% of the light ferrous in the feed;

(2) light ferrous stream--shall contain at least 98% of the light ferrous in the feed, with not more than 25% of the loose nonmetallics in the feed and none of the heavy ferrous metal;

(3) heavy ferrous stream--shall contain all of the heavy ferrous in the feed, with not more than 2% of the light ferrous and less than 15% of the loose nonmetallics in the feed. It shall include ferrous pipe or rod from 5" to 36" long and twisted mixtures of wire and organic material from 1 to 3 ft in diameter and having a bulk density of 5 to 6 lb/ft^3.

Light Ferrous Shredder (#208)

The light ferrous shredder used in the modified system is a modified horizontal-shaft hammermill, a Gruendler 30-2. The shredder rotor is driven at 920 rpm by a 50 hp electric motor. The 16 swing-type hammers are arranged in four rows of four hammers (alternating stations) per row. Tests of the modified shredder were conducted prior to installation in the modified system [5, 6]. This final shredder configuration is depicted in Figure 4. Figure 5 illustrates a typical hammer from the full complement of 16. The hammers were cast from 4140 high-manganese steel and were hardfaced on the working surface from the corner of the broad face to a point level with the top of the trapezoid (as shown by the shading in Figure 5) with Stoody 110 hardfacing wire. The Brinell hardness of the hardfacing is 500 whereas that of the hammer steel is 450. The hammers were in operation for 19.2 hours (Line #2 only) prior to the test period to allow slag, scale, etc. to be chipped off, thus allowing a typical hammer wear rate to be determined in the test. Finally, Figure 6 illustrates the grate configuration used in the shredder.

The shredder was rated to process 3 tph with surges to 5 tph.

Shredder Discharge Conveyor (#209)

The shredder discharge conveyor is a vibrating metal pan conveyor, 2 ft wide x 10 ft long, with 6 in. high walls, which was modified to have the end 3 ft of nonmagnetic steel under the electromagnet. A 1/2 hp electric motor drives this conveyor which is declined 7° below the horizontal.

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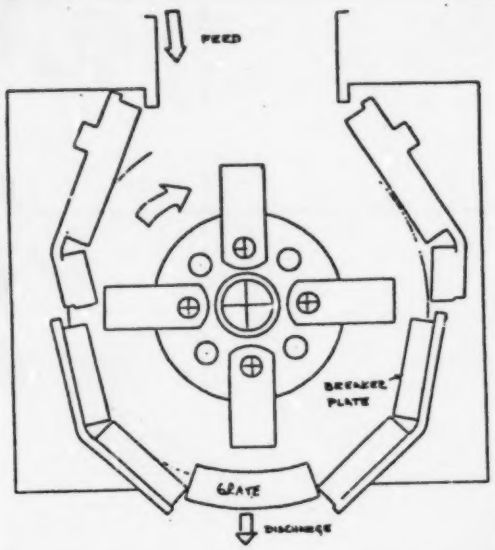

Figure 4. Ferrous shredder (#207) internals, side view.

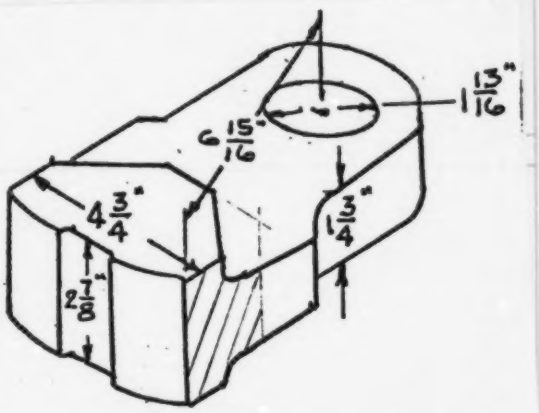

Figure 5. Ferrous shredder hammer, Gruendler pattern no. XXGB1A

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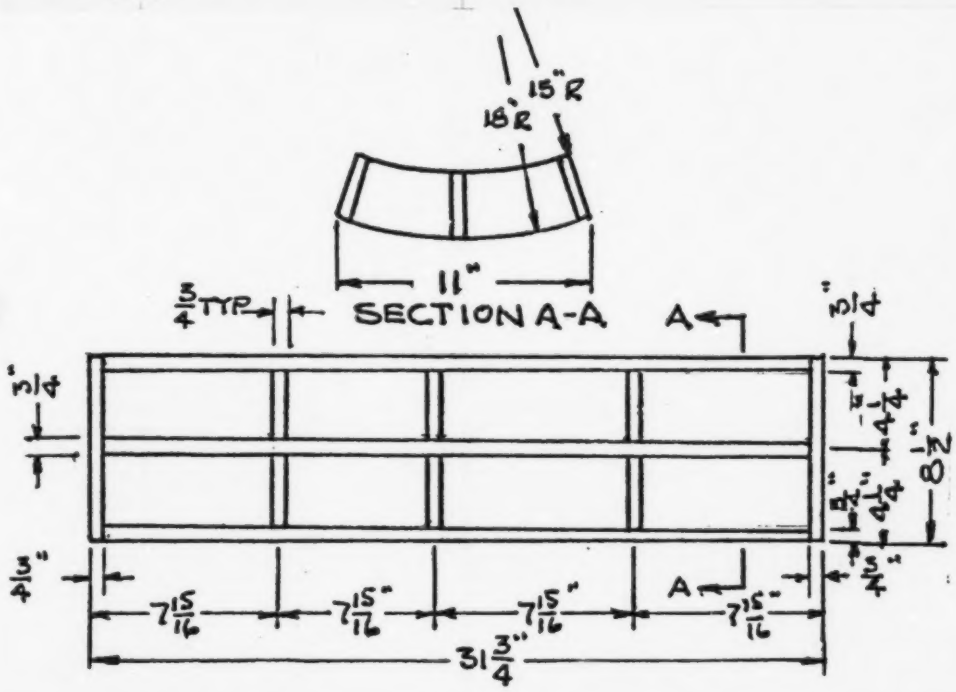

Figure 6. Ferrous shredder grate.

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Secondary Magnet (#210)

The secondary magnet used to clean the shredder light ferrous was supplied by Eriez Magnetics. A 2 hp electric motor powers a 30 in. wide belt cladded with segmented 15 in. wide centrally located stainless steel. A 3 kw rectifier energizes the electromagnet. The design air gap of approximately 7 in. between the end of the shredder discharge conveyor pan and the 2-3/4 in. high magnet cleats would provide a field strength of 750 gauss at the conveyor. After several tuning adjustments prior to the test, the magnet was inclined 1.5° above the horizontal in its direction of travel, with a maximum air gap of 11-1/4 in. The discharge end of conveyor #209 is located 2 in. short of the longitudinal centerline of the 90°-oriented (as viewed from above) magnet #210.

From the previously conducted tests of the shredder with secondary magnetic cleaning [5, 6] and from discussions with the customer, criteria for the light ferrous product were developed. These were: (1) maximum contamination, 4% (wt.); (2) bulk density, 21.5-26.0 lb/ft^3; and (3) shred size, maximum of 5% (wt.) less than 1 in.

Contaminants Discharge Conveyor (#211)

This conveyor receives the #210 magnet tailings and the light nonmetallics from #215 cyclone and discharges them into the plant's landfill-loadout system. This cleated 18 in. wide troughed-belt conveyor is inclined to 31° and has covers to reduce housekeeping. It is driven at approximately 100 fpm by a 2 hp electric motor.

Light Ferrous Product Conveyor (#212)

This conveyor carries the product from the discharge of #210 magnet to the railcar via a chute that bypasses the #198 compactor. This 18 in. wide flexowall conveyor is inclined at 43° and is covered to prevent contamination of the product. It is driven by a 3 hp electric motor at approximately 100 fpm.

TEST PROCEDURE

Ferrous System Stream Samplings

Rather than a relatively few in-concert samplings of the system output streams, a number of sequential samplings of feed and discharge streams under usual, but documented, operating conditions for Line #2 and Line #1 was conducted. Each group of five sequential samples, i.e., one sample each of the "feed" stream to the #207 air knife, the "heavies" stream from the air knife, the "light nonmetallics" stream from the air knife, the

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#210 magnet "tailings" stream, and the magnet "product" stream, was then known as a sample set. Four sample sets were obtained under Line #2 operation and two under Line #1 operation. Without exception, each sample for all streams was collected for 30 seconds. For sample sets 1-4 (Line #2 operation), the order of collection was: (1) feed; (2) heavies; (3) tailings; (4) product; and (5) light nonmetallics. To facilitate more closely time-related samplings, the smaller heavies sample was collected before the feed sample in sample sets 5 and 6 (Line #1 operation). The time to collect an entire sample set ranged from 26 (sample set 4) to 91 minutes (sample set 3) with the mean, 50 minutes. These times do not necessarily represent the processing time during the period of sample set collection because often a delay (no processing) due to unavailability of a loadout trailer interrupted the samplings.

The descriptions below detail the operating parameter data gathering and sample collecting procedures used.

Pre- and Post-Sampling Data Gathering--

Before each sample set collection, a recording ammeter was attached to one of the three phase wires supplying electricity to the #208 shredder motor. The recording ammeter printed the amperage at 5-second intervals. To synchronize the recorded amperage with the time of the samplings, a time index was placed on the recorder tape and the same watch used for the index was also used in recording the time of the actual samplings.

Immediately before the first sample and immediately after the last sample of a set, the following data were gathered:

(1) Pit #1 or #2 conveyor speed (indicator of processing line feed rate);

(2) Trommel unders magnet (#170) and/or shredded material magnet (#171) supply amperage and voltage (DC), elapsed-time meter readings, and the #171 magnet air gap;

(3) Air knife blower (#207) motor amperage and voltage (AC) and upper and lower air knife slot openings. (The fresh air damper to the blower inlet was closed and the diverters and baffles were in the same position for all samples.) For one of the sample sets, the corresponding air flow was measured at the inlet to the blower using a pitot tube/manometer to effect a traverse across the inlet duct. Air temperature was also measured; the recirculated air was approximately 15°F hotter than ambient air.

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Sample Collection--

At least three minutes of continuous processing preceded any sampling. The sequential samplings, in chronological order (Line #1 operation), are described below:

(1) Heavies stream--at a signal, one of the three samplers rotates the heavies conveyor (#178) discharge chute so that the free-falling stream lands in a 1 yd^3 plywood box; at the end of the 30-second sampling interval, a signal is given to reverse the rotation away from the sampling box. The lead sampler records the sample start and stop times, then turns off the air knife blower (#207) to allow for steady operation to obtain the next sample, the air knife feed stream. During this waiting period, the heavies sample is removed from the box and placed in a 30-gal capacity trash can and covered.

(2) Feed stream--since the air knife blower was stopped, the feed to the air knife reported entirely to the air knife heavies discharge; therefore, an identical sampling procedure to that for the heavies is executed. For several feed samples, a second 30-gal container was required to unload the sampling box.

(3) Tailings stream--on signal, two samplers insert a burlap bag across the discharge end of the shredder discharge conveyor (#209), the magnet having attracted the product before it reached the end of the conveyor. At the end of the 30-second sampling interval, the signal is given to withdraw the burlap bag. The start-and-stop times are recorded; the contents of the burlap bag are transferred to a 30-gal capacity plastic bag and sealed.

(4) Product stream--this most complicated sampling begins with the insertion of a plywood board in the magnet product discharge to direct it to the tailings chute. After about 5 seconds (enough time for the tail of #212 conveyor to clear), #212 conveyor is stopped, then a signal is given to remove the board; after 30 seconds, a signal is given to replace the board. The magnet (#210) coil is immediately de-energized to direct all of the shredder discharge to the tailings conveyor (#211). The product collected on #212 conveyor is withdrawn and placed in a 30-gal plastic bag.

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Immediately after withdrawal, the #212 conveyor and #210 magnet coil are restarted. The start-and-stop sampling times are recorded.

(5) Light nonmetallic stream--an access door in the #215 cyclone rotary air lock discharge chute is opened; a signal is given to insert a specially fabricated plywood box that directs the entire stream into the box. After 30 seconds, the signal to remove the box is given; the start and stop times are recorded; the contents of the box are transferred to a 30-gal plastic bag.

Shredder Performance

Hammer Wear--

After the nearly 20 hours of "wear in" before the ferrous system samplings began, the hammers described in the equipment subsection were removed from the shredder and thoroughly cleaned with a 200°F, high pressure water spray washer. Care was taken to inspect and remove any residual foreign matter. To insure that no moisture remained in several small superficial pits, the hammers were dried at 230°F for 4 hours. The hammers were then weighed to the nearest gram on a 20kg capacity beam balance. The 16 hammers were then balanced, i.e., the hammers were grouped in four groups (rows) of four hammers each so that no group total weight differed by more than 10g from any other group total weight. Each group of four "balanced" hammers constituted a row of hammers to be installed in the shredder. Prior to reinstallation, each hammer was imprinted with an identification number which indicated its location or station on the shredder rotor.

The hammers were reinstalled (one hammer was installed with its unhardfaced surface as the working surface) and functioned for 53.1 hours under Line #2 operating conditions for ferrous recovery and 7.7 hours under Line #1 conditions between April 28 and May 22, 1980, a period which included all Line #2 sample set collections. The operating times cited above were obtained from the elapsed time meter (ETM) readings for the trommel unders magnet (#170) and shredded material magnet (#171) at the time of hammer reinstallation and hammer removal. These meters are electrically connected to reflect nearly the time that refuse is being processed under an operating magnet and hence the ferrous recovery system operating time.

At the end of the test period (May 22), the hammers were removed from the shredder, then washed, dried, and weighed as described above. The weight loss for each hammer was calculated from the weights measured before and after the test period.

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Shredder Energy Consumption--

As mentioned above, shredder motor current was recorded for a leg of the three phase power supply at 5-second intervals throughout the collection of each sample set. Supply voltage was also checked at the beginning and end of the sample set collection. To measure shredder energy consumption for each sample set using these data, the following procedure was used:

(1) A 30-second interval, beginning 20 seconds before the magnet product was collected (corresponds to the travel time from the shredder to the sampling point) was identified on the recorder tape.

(2) For each current measurement, a power factor value was interpolated using data supplied by the motor manufacturer.

(3) Work done during each 5-second interval was computed from the equation

$$W = \sqrt{3}EItPF$$

where

W = work, joules
E = (begin + end volts)/2
I = current, amperes
t = 5 seconds
PF = power factor

(4) Work done was summed over the identified 30-second interval. Note that the shredder throughput for each sample set is the sum of the magnet product and tailings mass flow rates whereas the energy consumption computation was for the product interval alone. Since the tailings represented a small fraction of the sum, the error introduced by this approximation was also considered small.

SAMPLE ANALYSES

The analyses for each sample of a sample set are described below. The labor required to complete the analysis for an entire sample set was approximately 20 man-hours.

Feed

(1) Initial weight is measured using a 55 kg capacity beam balance with 5g readability by interpolation.

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(2) Volume occupied by the sample is measured as follows:

(a) Load a 2-1/2 ft^3 capacity fiber drum (23-3/4"H x 15-3/8" Dia.) about 1/3 full, then shake and rock until no further settling is observed.

(b) Continue adding sample in increments equal to about 1/3 drum volume and repeat shaking; if two drums are necessary, split the sample equally between the two drums.

(c) Measure depth below the top edge of the drum at four points around the drum periphery at 90° apart and one point at the center. The average of the five depths is used to compute volume occupied.

(3) Sort the entire sample into loose contamination, can (and related material), and noncan ferrous. Weigh and record each sorted portion. Check sum of weights against initial weight.

(4) Screen the can and noncan portions separately for 10 minutes or until no particles pass the screens using 4", 2", 1", 1/2", and 1/4" sieves on the 2-1/3 ft^2 Gibson testing screen. Several loadings may be necessary. Weigh and record each size fraction from the can and noncan portions; check sums against the respective starting weights.

(5) Obtain the clean magnetic metal weight for the can portion by using the "Cleaned Can Catalogue" procedure [5] for the identifiable can material and hand washing for the rest; the hand-washed cans are dried at 230°F in a convection oven at least overnight.

(6) Obtain the clean magnetic metal weight for the noncan portion by using tools to remove nonmagnetic material or by washing or by burning at 750°F for 1 hr in a muffle furnace. The hand-washed cans are dried at 230°F in a convection oven at least overnight.

Heavies

(1) Initial weight is measured as for the feed sample.

(2) Volume occupied by the sample is measured as for the feed sample.

(3) Sort the entire sample as for the feed sample.

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(4) For the can and noncan sorted portions, a "drop test" is used to determine whether each particle is aerodynamically light or heavy. Each particle is dropped from a height of 28 ft. The person timing starts the stopwatch with the release and stops it with the impact on the floor. Each particle is oriented for minimum frontal area before the release. After numerous trials, a fall time of 1.30 sec designated the point for aerodynamically light or heavy classification, i.e., a fall time of 1.30 sec or longer designated a particle as aerodynamically light. Weigh the aerodynamically light and heavy material from the can and noncan portions; check the sums against the starting weights.

(5) Obtain the clean magnetic metal weights separately for the aerodynamically light and heavy fractions of the can portion by using the methods described for the feed sample.

Magnet Tailings and Light Nonmetallics

(1) Initial weight is measured using a 2,610g capacity triple-beam balance to 0.1g readability.

(2) Sort entire sample into loose contamination and ferrous categories; check sum against initial weight.

(3) Obtain the clean magnetic metal weight for the ferrous material by any of the methods for can and noncan material, as described above.

Product

(1) Initial weight is obtained as for the feed sample.

(2) Volume occupied by the sample is measured as for the feed sample.

(3) Sort the entire sample into loose contamination and ferrous categories; check sum against the initial weight.

(4) Screen the ferrous category as for the feed sample.

(5) Sort the ferrous material into noncan, "balled" cans, nonballed cans, and "unsure" balled cans. The criterion for the balled-can category was the inaccessibility of most of the interior and exterior surfaces to water (i.e., relatively unsuited for chemical detinning). Weigh each sorted category; check sum against sum of size fractions.

(6) Recombine all ferrous categories; divide the ferrous using a 4" slot opening Gibson riffler to provide a subsample of about 1/2 ft^3. Only the sample from set 3 required more than

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one riffling to provide the subsample for contamination analysis. Check subsample sum against starting weight.

(7) Measure attached contamination by heating the 1/2 ft^3 subsample in a 1 ft^3 natural convection oven at 500°F for 24-26 hours. The oven is located in a fume hood with the blower on. Check oven temperature periodically and record most frequently noted temperature. After prescribed heating period, weigh sample in its galvanized steel container on 55 kg balance. Screen the heated sample on 1" and 1/4" sieves of Gibson screen for 10 min. Remove and combine material from the two screens and add magnetic material extracted from the pan. Weigh this remaining magnetic material on the same balance as above. Discard the ash from pan and any nonmagnetic fragments removed from the larger magnetics. Repeat analysis for another subsample if anomalous results are obtained (done for sample nos. 5 and 6).

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SECTION 3

TEST RESULTS

SYSTEM OPERATING CONDITIONS

The principal operating parameters for all the sampling sets are shown in Table 1. There was little variability in operating conditions for Line #2 samplings except for the air knife blower current for the fourth sample set. There had been increasing resistance for air flow in sets no. 1-3 due to an accumulation of textiles, plastic, and wire at the #215 cyclone tangential entrance, which was cleaned before set no. 4. With the lower resistance, it was necessary to throttle the lower air knife slot to bring the blower current (output) relatively close to the previous samplings. Even so, the air knife heavies stream was noticeably reduced in misreporting can ferrous. Nevertheless, all four samplings were considered equally valid because of the recurring nature of the accumulation in the cyclone. By the time No. 5 and 6 samplings occurred, blower output was diminishing, even with both air knife slots open again, because of renewed accumulation.

TABLE 1. OPERATING PARAMETERS FOR SAMPLINGS

Parameter	Line #2 Operation					Line #1 Op.		
	1	2	3	4	Comp.	5	6	Comp.
Pit conveyor speed, fpm	7.70	7.52	7.35	7.57	7.54	6.60	7.16	6.88
Est. processing line feed rate, tph	120	118	115	118	118	103	112	108
#171 primary magnet gap, in.	20.2	19.9	19.9	19.9	20.0	20.2	20.0	20.1
#207 blower current at 480V	57	59	58	63	59	68	65	66
Vol. output, cfm At temperature				9380 106°F				

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SYSTEM MATERIALS BALANCE

As described earlier in Section 2, the analyses of the system various output and feed samples were not identical; therefore, to compile Table 2 it was necessary to make several reasonable assumptions or approximations:

(1) the percent attached contamination of the can and noncan ferrous in the secondary magnet product stream was the same;

(2) the percent attached contamination of the noncan ferrous in the feed stream (formed by summing the output streams) was the same as that in the sampled feed stream and none was liberated during shredding;

(3) the ferrous in the light nonmetallics stream and the magnet tailings stream was can ferrous; and

(4) the percent loose contamination in the feed stream (formed by summing the output streams) was the same as that in the sampled feed stream.

From Table 2, Line #2 operation, it can be seen that 31% of the target can ferrous metal (clean) was lost to the air knife heavies stream; however, only 34% of this lost can ferrous metal was "aerodynamically light" which would bring this loss of can metal to 12% if this unseparable can metal were excluded from the feed and heavies. Similarly, from Table 3, Line #1 operation, 40% of the can metal was lost to the heavies; 27% of that lost was aerodynamically light which would bring this loss to 12% if similarly excluded. This loss might be further reduced if some of this aerodynamically heavy can ferrous found in the heavies stream had initially been "light," blown properly into the shredder but had ricocheted from the shredder and air knife then out to the heavies stream. This phenomenon was not quantifiable because it was not possible to distinguish between aerodynamically heavy cans from #208 shredder ricochet and those from the primary shredder. Further efforts to reduce the #208 shredder ricochet through the air knife are called for.

Of the can metal in the feed, 3% was lost to the air knife "flies" or light nonmetallics stream in Line #2 operation and 7% in Line #1 operation. This higher loss in Line #1 operation was expected because of higher air flow rate in the air knife and the higher concentration of unshredded and lid-like can material in the air knife feed in Line #1 operation compared to Line #2. Only 1% of the can metal in the system feed was lost from the second magnet for both Line #1 and #2 operation. The recovery

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TABLE 2. FERROUS RECOVERY SYSTEM MATERIALS BALANCE
Line #2 Operation (Composite Samplings 1-4)
(lb/hr, as received)

	A/K Feed	A/K Heavies	A/K Flies	A/K Lights and Shredder Feed	Shredder Disch. and Magnet Feed	Magnet Tailings	Magnet Product
Loose Contam.	114	13	66	36	147	134	13
Can Ferrous	4290	1328	142	2819	2708	41	2667
Clean metal	3977	1246	135	2596	2596	38	2558
Attached Contam.	312	82	7	223	112	5	109
Noncan Ferrous	1632	1051	0	582	582	0	582
Clean metal	1540	982	0	558	558	0	558
Attached Contam.	93	69	0	24	24	0	24
Total Ferrous	5922	2379	142	3401	3289	41	3248
Clean metal	5517	2228	135	3154	3154	38	3116
Attached Contam.	405	151	7	247	135	3	132
Total	6036	2392	208	3436	3436	175	3262
Bulk density, lb/ft^3		21.1					26.7

NOTE: Sums may not equal totals because of rounding.

TABLE 3. FERROUS RECOVERY SYSTEM MATERIALS BALANCE
Line #1 Operation (Composite Samplings 5-6)
(lb/hr, as received)

	A/K Feed	A/K Heavies	A/K Flies	A/K Lights and Shredder Feed	Shredder Disch. and Magnet Feed	Magnet Tailings	Magnet Product
Loose Contam.	135	6	65	64	145	137	8
Can Ferrous	4536	1847	298	2390	2309	53	2256
Clean metal	4182	1680	278	2223	2223	40	2184
Attached contam.	354	167	20	167	86	13	73
Noncan Ferrous	1558	1144	0	414	414	0	414
Clean metal	1473	1073	0	400	414	0	400
Attached contam.	85	71	0	13	13	0	13
Total Ferrous	6094	2992	298	2804	2723	53	2670
Clean metal	5655	2753	278	2624	2624	40	2584
Attached contam.	439	238	20	181	99	13	86
Total	6229	2998	363	2868	2868	190	2678
Bulk Density		27.7					24.5

NOTE: Sums may not equal totals because of rounding.

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of the target can metal from air knife feed to product was 64% in Line #2 operation and 52% in Line #1 operation.

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Of the can-ferrous attached contamination in the air knife feed, 71% reported to the air knife lights (shredder) in Line #2 operation and 47% in Line #1 operation. The can-ferrous attached contamination in the heavies was 6.2% and in the lights, 7.9% for Line #2 operation, whereas for Line #1 operation it was 9.0% and 7.0%, respectively. This probably reflects the different character of the can material originating from Line #2 and #1 operation, i.e., the cans likely to report the heavies in Line #2 operation are likely densified through the primary shredder (contamination liberated consequently) whereas those in Line #1 operation likely to do the same are those dense because of heavy contamination (unshredded because they passed through the trommel holes).

About half of the can-ferrous attached contamination in the ferrous shredder feed was liberated by its processing in both Line #2 and #1 operation. This reduced the can-ferrous attached contamination from 7.9% to 4.1% for Line #2 and 7.0% to 3.7% for Line #1 operation.

From the estimated processing line feed rates in Table 1 and 2.72% can ferrous metal average content in raw refuse [6], the overall processing line recovery (included primary magnetic extraction) of can ferrous metal is 40% and 37% for Lines #2 and #1, respectively. Also, the efficiency of #171 drum magnet in Line #2 operation is estimated similarly by using the can ferrous metal in the air knife feed (equivalent to #171 product) to be 62%.

SYSTEM FEED AND PRODUCT CHARACTERISTICS

Table 4 shows the characteristics of the air knife feed, formed by summing its output streams (per Tables 2 and 3) and from the feed samples analyzed, and the secondary magnet (and system) product. As can be seen, the bulk density of the product is substantially higher than that of the feed. For both processing line operations, the minimum required bulk density for the product, 21.5 lb/ft^3, was exceeded. The product rates were 1.63 and 1.34 tph for Line #2 and #1 operation, respectively. There was less than 4% difference between the air knife feed rate from the sum of the outputs and the actual feed samples for Line #2 operation. Contrasted, there was about 19% difference for Line #1. This fact, only two samplings, and the noted differences in shredder power required between the feed and product samplings in a set, indicate that the product rate for Line #1 operation may be somewhat higher than the tabulated result.

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TABLE 4. FERROUS RECOVERY SYSTEM FEED AND PRODUCT CHARACTERISTICS
(from composite of samples)

	Line #2 Operation			Line #1 Operation		
	A/K Feed (Sampling)	A/K Feed (Σ outputs)	Magnet Product	A/K Feed (Sampling)	A/F Feed (Σ outputs)	Magnet Product
Bulk density, lb/ft^3	16.2		26.7	17.0		24.5
Mass hour rate, tph	3.138	3.018	1.631	3.853	3.115	1.339
Loose Contamination, % wt.	1.9	1.9	0.4	2.2	2.2	0.3
Can Ferrous, % wt.	73.4	71.1	81.8	68.6	72.8	84.3
at % contamination	7.4	7.3		10.6	7.8	
Noncan Ferrous, % wt.	24.8	27.0	17.8	29.2	25.0	15.4
at % contamination	5.7	5.7		5.4	5.4	
Total Ferrous, % wt.	98.1	98.1	99.6	97.8	97.8	99.7
at % contamination	7.0	6.8	4.1	9.1	7.2	3.2
Total Contamination, % wt.	8.7	8.6	4.5	11.1	9.2	3.5
Ferrous PSD, % wt.						
+4"	12.0		0.2	1.4		0
-4"+2"	60.5		32.2	59.0		24.3
-2"+1"	22.8		57.2	28.2		62.5
-1"+1/2"	3.2		7.7	8.1		9.3
-1/2"+1/4"	0.9		1.5	2.1		1.9
-1/4"	0.5		1.3	1.3		1.5
Total	100		100	100		100

NOTE: All % (wt.) on as received basis.

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The composition of the feed for Line #2 operation was quite similar to that of Line #1; whereas, the attached contamination to the can ferrous was somewhat higher, 10.6% for Line #1 compared to 7.4% for Line #2. This lower can and total ferrous contamination for Line #2 feed is attributed to the primary shredder and the differential separation by the #171 primary magnet [4]. The particle-size distribution (PSD) of the ferrous in the feed shows a somewhat smaller size for Line #1; this is attributed to the higher recovery of smaller ferrous by the #170 primary magnet [3].

The composition of the magnet or final product was quite similar for Lines #2 and #1; attached contamination was somewhat higher for Line #2 operation, 4.1% compared to 3.2% for Line #1. This may be attributable to the commingling of all the ferrous in the primary shredder for Line #2 operation. Total contamination of the product was slightly higher in Line #2 operation (4.5%) than the target specification of 4% and slightly lower (3.5%) for Line #1 operation. The PSD of the ferrous in the product showed a smaller size for Line #1 operation which is consistent with the smaller PSD for the feed as compared to Line #2. The fraction of the product that was -1" exceeded the target specification of not more than 5%; however, note that the feed contained 4.6% and 11.5% of -1" ferrous for Lines #2 and #1 operation, respectively.

AIR KNIFE PERFORMANCE

Table 5 compares the performance of the air knife found for Line #2 and #1 operation, to the manufacturers performance specification. Only the loose nonmetallics (contamination) mass split specification to the air knife heavies stream was met. Because the air knife lights (shredder feed) was not sampled, per se, it was not possible to determine whether the noncan ferrous found in the shredder discharge was aerodynamically light or heavy; hence, the performance regarding noncan ferrous mass split to the air knife lights was unknown. There were no shredder jams from noncan ferrous during any of the six samplings. It was determined, however, that 3.3% and 5.5% of the noncan ferrous in the heavies stream was aerodynamically light for Line #2 and #1 operation, respectively.

The most serious deficiency, of course, was the can ferrous mass split to the air knife lights. The inability of the air knife blower to deliver the rated 15,000 cfm was a major factor in this result; however, increased air flow would then increase the amount of can ferrous flown and lost. A sustained increase in blower output with possible adjustment/modification of the air knife interior diverters and baffles is the logical next step in improving air knife performance.

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TABLE 5. AIR KNIFE PERFORMANCE
(wt. % as received basis)

COMPONENT: mass split, %	Ferrous A/K Performance Spec.	Line #2 Operation (Composite of 1-4)		Line #1 Operation (Composite of 5-6)	
		*	**	*	**
Loose Nonmetallics: in fly stream / in feed stream	Min. 75%	57.7%	57.7%	48.0%	48.7%
Ferrous can: fly / feed	Max. 2%	3.3	4.2	6.6	9.2
Loose Nonmetallics: lights (to shredder) / feed	Max. 25%	31.1	31.1	47.2	47.8
Ferrous Can: lights (to shredder) / feed	Min. 98%	65.7	82.3	52.7	73.9
Ferrous Noncan: lights (to shredder) / feed	0%	35.6	unknown	26.5	unknown
Loose Nonmetallics: heavies / feed	Max. 15%	11.2	11.2	4.7	3.5
Ferrous Can: heavies / feed	Max. 2%	31.0	13.5	40.7	16.9
Ferrous Noncan: heavies / feed	100%	64.4	unknown	73.5	unknown

* Based on sorted category irrespective of whether A/K could separate aerodynamically.

** Based on sorted category with aerodynamically heavy portion in heavies stream excluded.

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SHREDDER PERFORMANCE

Energy Consumption

Table 6 shows the ferrous shredder energy demands for each of the product samplings and the composite for each operating line. Also shown are several shredder feed and output characteristics. Note that in sampling no. 3, that there was considerably more noncan ferrous in the shredder feed than in the other three Line #2 samplings. This feed characteristic along with the lower feed contamination level may explain the increase in specific energy rather than the continued decrease in specific energy as the shredder feed rate increased. Also, notable for the no. 3 sampling is the substantially lower percentage of the can ferrous that was balled. From the composites, the percent of can ferrous that was balled was higher from Line #2 operation than that from Line #1. This is attributable to Line #2 product can ferrous encountering two shredding steps. The specific energy for Line #2 and #1 operation at comparable feed rates did not differ substantially. The 50 hp shredder motor was not heavily taxed with the range of power demand of 22 to 32 hp for the 30-second samplings.

Hammer Wear

Table 7 shows the position or station of each hammer and the hammer weights when installed and removed for the test period. The primary magnets' elapsed time meters indicated 53.08 hr of Line #2 ferrous recovery and 7.74 hr of Line #1 recovery during the test period. All four Line #2 samplings were conducted within that period. For 41.40 hr of that operation one railcar was filled with 74,900 lb of product or a product rate of 0.90 tph; substantially less than the product rates obtained from the samplings. The conclusion was drawn that the #171 magnet ETM was yielding a higher recovery operating time than actual; therefore, the quantity of product produced in the test period was calculated using the 0.90 tph figure, or 55.0 tons. From this quantity of product and the materials balance for the secondary magnets in Line #2 and #1 operation, 58.1 tons was calculated as the tons shredded during the test period. From the total weight loss from the hammers during the period, 1.20 lb, the wear rate was then 0.021 lb/ton (pounds of hammer wear/ton processed). This wear rate is lower than that for the previous mild steel hammers, about 0.03 lb/ton.

Note that the average hammer weight loss (wear) for the four outboard hammers (41.5g) was substantially higher (22%) than for all hammers (34g). Also note that the hammer without hardfacing (station B3) had the highest weight loss, 45g, which is 32% greater wear than the average and 45% greater wear than

TABLE 6. SHREDDER ENERGY CONSUMPTION

Sample Set	Line #2 Operation 1	2	3	4	Comp.	Line #1 Operation 5	6	Comp.
Shredder Feed Rate, tph	1.165	1.886	2.354	1.468	1.718	1.708	1.160	1.434
Feed, % total contamination	9.2	9.9	5.9	8.8	8.1	8.1	9.1	8.5
Feed, % noncan	9.8	14.3	23.8	14.9	16.9	15.0	13.6	14.4
Output, % -1"*	8.3	12.9	9.6	10.3	10.4	11.3	14.8	12.7
Output, % of can balled*	32.5	31.3	13.3	32.5	26.0	20.4	17.8	19.4
Power consumption, hp	24.3	25.3	32.4	22.2	26.1	25.7	22.0	23.8
Power consumed above idle, hp	6.1	7.0	14.6	3.5	7.8	7.3	3.4	5.4
Specific energy, hp-hr/T	20.9	13.4	13.8	15.1	15.2	15.0	19.0	16.6

* Shredder discharge assumed equivalent to secondary magnet product.

TABLE 7. SHREDDER HAMMER CONFIGURATION AND WEAR
(Weight in Grams)

Hammer Type: Gruendler XXGBIA with Stoody 110 hardface
Installed: 4/28/80
Removed: 5/22/80

	Station								
Pin	1	1	2	2	3	3	4	4	Total
A		9,187g(installed)		8,932		8,840		9,082	36,041
		9,159g(removed)		8,900		8,810		9,040	35,909
		28g(loss)		32		30		42	132
B	8,874		9,011		9,221*		8,943		36,049
	8,838		8,978		9,176		8,908		35,900
	36		33		45		35		149
C		9,285		9,168		8,534		9,055	36,042
		9,259		9,138		8,508		9,012	35,917
		26		30		26		43	125
D	9,203		9,063		8,927		8,850		36,043
	9,158		9,033		8,895		8,818		35,904
	45		30		32		32		139
Total	18,077	18,472	18,074	18,100	18,148	17,374	17,793	18,137	144,175
	17,996	18,418	18,011	18,038	18,071	17,318	17,726	18,052	143,630
	81	54	63	62	77	56	67	85	545

Fe Proc (T)	HMR wear (lb)	Wear Rate (lb/T)
58.1	1.20	0.021

A-B-C-D in CCW order, as viewed from North

* no hardfacing

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the average for its six nearest neighboring hammers. It appears that the hardfacing substantially reduces hammer wear.

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SECONDARY MAGNET PERFORMANCE

Table 8 shows the mass balance and composition of the magnet feed and discharge streams as well as performance parameters. The percent loose contamination in the magnet feed was similar and low for both Line #2 and Line #1 operation; 4.3% and 5.0%, respectively. The recovery of ferrous metal was very high, nearly 99%, in spite of the substantially larger than design air gap, 11 in. rather than 7 in. Of the loose contamination in the magnet feed, 9.2% was carried over into the product during Line #2 operation and 5.4% during Line #1 operation.

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TABLE 8. SECONDARY MAGNET PERFORMANCE

	Line #2 Operation (composite of 1-4)	Line #1 Operation (composite of 5-6)
Magnet Feed Rate, tph	1.718	1.434
% Loose Contamination	4.3	5.0
% Ferrous Metal	91.8	91.5
% Attached Contamination	3.9	3.5
Tailings Flow Rate, tph	0.087	0.095
% Loose Contamination	76.4	72.2
% Ferrous Metal	21.8	20.8
% Attached Contamination	1.8	7.0
Product Flow Rate, tph	1.631	1.339
% Loose Contamination	0.4	0.3
% Ferrous Metal	95.5	96.5
% Attached Contamination	4.1	3.2
% Mass Split to Product	94.9	93.4
% Recovery Ferrous Metal	98.8	98.5
% Carryover Loose Contamination	9.2	5.4

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IMPROVEMENT OF MAGNETICALLY SEPARATED FERROUS CONCENTRATE BY SHREDDING: A PERFORMANCE TEST

Test No. 4.07, Recovery 1, New Orleans

by

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